Collider-Accelerator Department

BROOKHAVEN NATIONAL LABORATORY

Building 911B – P.O. Box 5000
Upton, NY 11973-5000
Phone 631 344 7124
Fax 631 344 5568
beavis@bnl.gov
www.bnl.gov

managed by Brookhaven Science Associates
for the U.S. Department of Energy

# Memo

*Date:* *April 17, 2015*

*To:* *H. Huang, W. Fischer, P. Cirnigliaro, P. Ingrassia & RSC*

*From:* *D. Beavis*

*Subject:* *Radiation Measurements at the AGS Escape Hatch Doors with Proton Operations*

## Motivation

It has been requested that areas that have been posted as High Radiation Areas be examined to determine if their posting can be reduced to Radiation Area or Controlled Area. A phased approach has been selected for the High Radiation Area fences around the AGS escape hatches. The alarm levels of the chipmunks in the B and D fan houses will be changed but the interlock levels will remain unchanged. **If the new alarm levels do not become a nuisance then on the next maintenance day the interlock levels will be lowered and the fences reposted as Radiation Areas.** If the alarm levels become an issue for operations the area will be reposted as a High Radiation Area and the chipmunk thresholds increased as appropriate. The access to these areas will remain unchanged.

The fenced areas around the escape hatches were entered to conduct radiation measurements at the escape hatch doors. The measurements were conducted by an RCT using an HPI-1010. The location of the measurement was in contact with the door at head height. The C14 escape hatch had a measured dose rate of 0.15 mrem/hr, which was obtained by integrating for a two minute interval. The K7 escape hatch had a dose rate of 6 mrem/hr and was measured integrating for 30 seconds.

The chipmunk[1] in the B fan house protects[2] the area[3] around the K7 escape hatch and the chipmunk in the D fan house protects the area around the C14 escape hatch. During these measurements the beam was stable but the second measurement was conducted at higher beam intensity. A tune measurement finished after the measurement at the C14 fan house and the beam intensity was returned to normal levels for operations. The K7 escape hatch measurement occurred with an intensity of $2.3*10^{11}$ protons per 3.9 second cycle. The C14 escape hatch was conduct during the lower intensity of $1.3*10^{11}$ protons per cycle. The history of the AGS beam intensity during the time frame of the measurements is shown in Figure I. There was no beam for an interval of time around 15:30 that can be used to subtract the chipmunk background.

[1] The chipmunk presently has an interlock level of 50 mrem/hr and an alarm level of 20 mrem/hr.
[2] Each chipmunk also protects their respective fan house. Originally the chipmunks were placed on the top landing of the escape hatch stairs but there were numerous trips with high intensity beam and they were move to the fan houses.
[3] This includes both the area inside the fence and outside.

The chipmunk data for B fan house has a background rate of 0.27 mrem/hr and a net dose rate during the radiation measurement of 0.27 mrem/hr. The interlock dose rate on this chipmunk is 50 mrem/hr and the alarm rate is 20 mrem/hr. The dose rate at the K7 escape hatch door could rise to 440 mrem/hr before the chipmunk alarms and 1100 mrem/hr before the chipmunk interlocks. The area outside the fence has levels of 10 to 15 times lower[4] than the door. Since fault studies are not perfect and the one conducted for the escape hatch was conducted at 1.5 GeV it will be recommended that the interlock level be reduced to 20 mrem/hr and the alarm level to 5 mrem/hr. The 5 mrem/hr alarm rate will keep the door close or below a dose rate of 100 mrem/hr. The chipmunk is protecting adjacent areas for beam fault conditions and it is not required to keep the adjacent Radiation Area[5] below 100 mrem/hr, but it is desired to have the dose in a fault be less than 100 mrem in a Radiation Area, especially outside the fence. The fault study was conducted at 1.5 GeV, which typically would not have the equivalent high energy neutron dose component that a 28 GeV proton fault would create. This would be expected to create somewhat lower dose rate ratios of the escape hatch door to the fence perimeter. This is why it is desirable to lower the chipmunk interlock threshold for the B fan house chipmunk.

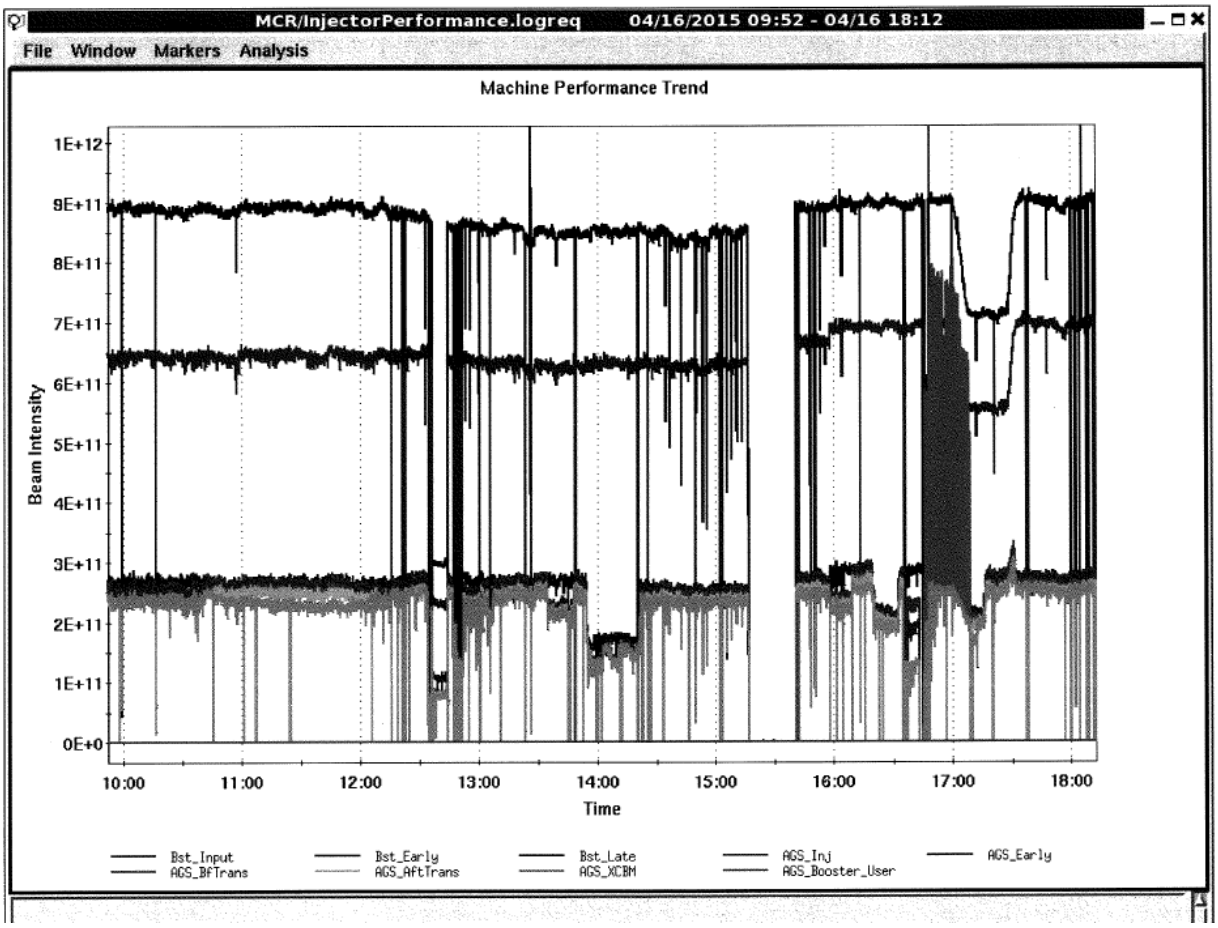

Figure I: Machine performance. Measurements conducted between 14:00 and 14:25.

[4] Based on examining AGS Ring fault study 36 conducted on April 4, 1995.
[5] The area outside the fence is posted as a Radiation Area.

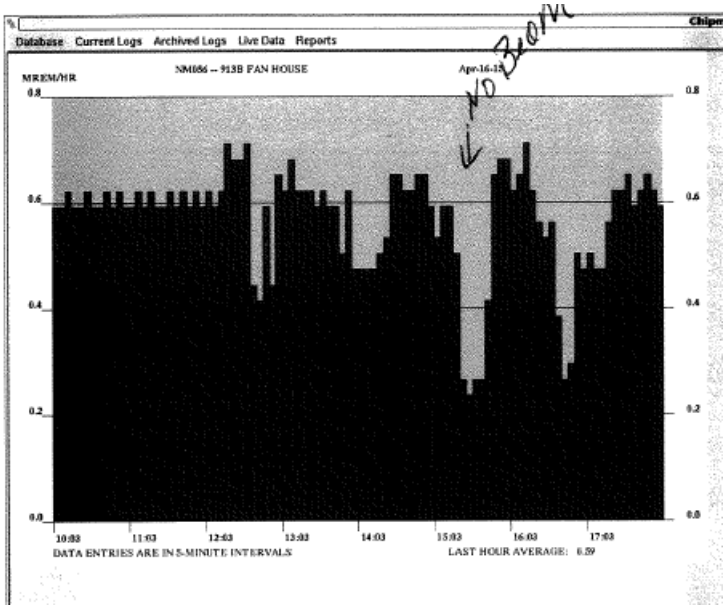

Figure II: B fan house chipmunk across from K7 escape hatch.

The chipmunk in the D fan house has no indications of beam loss. The dose rates at the C14 escape hatch door was measured as 0.15 mrem/hr. The alarm and interlock dose rate on the chipmunk are 50 and 20 mrem/hr, respectively. The design of the air duct systems for the B and D fan houses are identical[6]. Therefore one would expect equivalent potential fault conditions. However, the chipmunk in the D fan house is located farther away from the air duct system than the one in the B fan house. It should be less sensitive to the neutrons leaking out the air duct. For this chipmunk it is recommended that the interlock rate be lowered to 20 mrem/hr and the alarm threshold to 2.5 mrem/hr.

[6] See for example D. Beavis, AGS/EP&S/Tech Note 138, September 30, 1991; http://www.c-ad.bnl.gov/esfd/RSC/Memos/9_30_91_AGS.pdf

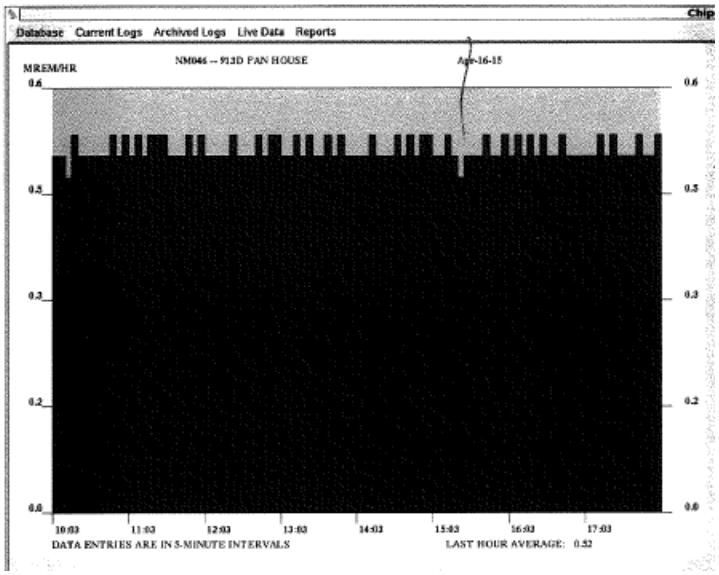

Figure III: The D fan house chipmunk across from the C14 escape hatch.

The fault study has been examined to investigate the protection level provided by the B and D fan house chipmunks. Only the B fan house chipmunk will be used here since the data was not significant for the D fan house chipmunk. No review or escalation of AGS ring FS 36 was found in the logs. The intensity of the beam was $3.6*10^{12}$ protons per 3.2 second cycle. The beam energy was 1.5 GeV. The fault was a vacuum valve which I will assume is 1 cm of iron. 6% of the beam will have an inelastic collision in the valve and the beam penetrating the valve will have a loss in energy of 1%. It is quite possible that this beam will travel substantially away from the interaction point. Scaling to full energy[7] provides a factor of 10.4. A 100% beam loss at full energy would require scaling the fault study results by a factor of 173. Table I provides scaled results for several locations.

**Table I: AGS Ring Fault Study at 3.6 TP Scaled for Full Loss and Energy**

| Location | F.S. Dose Rate (mrem/hr) | Scaled dose rate (mrem/hr) |
|---|---|---|
| **Escape hatch door** | 120 | 20780 |
| **Side of fence** | 12 | 2078 |
| **Fence gate** | 8 | 1390 |

Based on the present radiation measurements at the escape hatch door and recorded chipmunk readings we can create a similar table based on the new interlock (20 mrem/hr) and alarm levels (5 mrem/hr) for the B fan house chipmunk. The results are given in Table II.

**Table II: AGS Fault Study Scaled for New Chipmunk Settings**

| Location | Dose rate at Alarm level of 5 mrem/hr | Dose rate at interlock level of 20 mrem/hr |
|---|---|---|
| **Escape hatch door** | 111 | 440 |
| **Side of fence** | 11 | 40 |
| **Fence gate** | 7 | 30 |

[7] The transverse radiation has been scaled by $(28/1.5)^{0.8}$.

Radiation dose rates were predicted for various locations in Footnote 6 including the escape hatches. Scaling the predicted dose rates to the fault study intensity a dose rate of 450,000 mrem/hr is obtained at the door. In Footnote 6 it is noted that no credit was taken for attenuation in the magnet iron or other materials nearby. Using a factor of 5 for attenuation in the magnet iron would reduce the estimate to 90,000 mrem/hr at the escape hatch door. Considering the crudeness in scaling the fault study and the simplicity of the earlier estimates the 90,000 mrem/hr compares well with the 21,000 mrem/hr.

It is not known if full energy beam faults of this magnitude can be created near the escape hatches. Low energy faults have always been assumed to be possible at essentially any location.

There are two limits on proton beam intensity in the AGS ring that are lower than the ASE limit. The first is a hardware interlock using the B12 transformers. The transformers are in the access control system to limit the beam intensity to $2.5*10^{12}$ protons per cycle if beam can be transported to RHIC. The typical cycle time for RHIC is 3.9 seconds. The RSC established an administrative limit[8] on proton beam intensity when some shielding was removed from an access tunnel. This limit is $1.25*10^{17}$ nucleon-GeV/hr and is implemented[9] in OPM 6.5. At 28 GeV this limit corresponds to $5*10^{12}$ protons per 3.9 second cycle.
If the escape hatch fences are reposted as Radiation Areas then they should have posting on the fence even though they are already within a Radiation Area. This is being done since at some point there may be interest to repost the AGS ring berm as a Controlled Area.

[8] See RSC minutes of Dec. 16, 2008; http://www.c-ad.bnl.gov/esfd/RSC/Minutes/121608Minutes.pdf
[9] See OPM 6.5; http://www.c-ad.bnl.gov/esshq/snd/opm/Ch06/06-05.PDF